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ABSTRACT

Two previous papers of the Learning in Science Project recorded the thinking of the project team at the outset of the exploratory and in-depth phases of the project. This paper briefly reconsiders the work done in the in-depth phase and then discusses some central issues and tentative ideas as the project moves into the third and final "action-research" phase. Results of the in-depth phase demonstrated that children, even prior to entering intermediate school, often have clear-cut views of the world and meanings for many words used in science, and that these views/meanings are considerably different from the consensus view of scientists. In addition, the prevalence and resistance to change of children's non-scientific views are not fully appreciated by teachers or curriculum developers. Drawing on these and other in-depth findings, the following areas are discussed: problems related to science content/process; implications of same for instruction; modifying children's viewpoints; and science for everyone (considering two alternate approaches--science to technology and technology to science). Action research will involve four working groups focusing on issues raised in these discussions and in previous working papers, addressing issues related to biology, chemistry, physics, and science experiments/processes. (Five rules useful in planning instructional sequences are included.) (JN)

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LEARNING IN SCIENCE PROJECT

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THE FRAMEWORK:

TOWARD ACTION RESEARCH

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WORKING PAPER No. 28

The Framework: toward action research

A working paper of the Learning in Science Project

Roger Osborne*

February 1981

INTRODUCTION

Two previous working papers of the Learning in Science Project "An initial framework" and "Reconsidering the framework" recorded the thinking of the Project team at the outset of the exploratory, and the in-depth, phases of the project, respectively. This paper briefly reconsiders the work done in the in-depth phase and then discusses some central issues, and tentative ideas, at the point in time when the project moves into the third and final phase: the action-research phase.

THE IN-DEPTH PHASE

The Children's Science aspect of the work carried out in the in-depth phase of the project concentrated on finding out about children's meanings for words and children's views of the world with respect to a variety of topics. The terms and views investigated, and the working papers associated with the findings of each investigation, are listed in Table I. In general this work followed the pattern outlined in Working Paper No. 14 "Reconsidering the framework" although it was decided

(i) with regard to Physics topics to follow our study of FORCE, with associated studies of FRICTION and GRAVITY rather than consider the topic of WORK;

(ii) with regard to Chemistry topics to study children's ideas of PHYSICAL CHANGE, and CHEMICAL CHANGE as well as separately to study their ideas about PARTICLES; and

(iii) with regard to Biological topics to study PLANTS, ANIMALS and LIVING in some depth, and to replace the study of adaptation and energy flow with a study of ENERGY without restricting this to a biological context.

*see acknowledgements

These investigations of Children's Science were extensive, involving some eight full-time and part-time researchers and some 500 individual student interviews. It soon became clear to us that because of the general interest in this work, and the valuable information we were acquiring from it, our intended move from the in-depth to the action-research phase of the project in August 1980 needed reconsideration. While some action- research work, on ANIMALS, was begun in Term II 1980, action-research on FORCE, FRICTION and GRAVITY was rescheduled for Term I 1981.

Action-research on the Chemistry topics was rescheduled to begin in Term II 1981. This sliding change from in-depth to action-research allowed time for both discussion and organisation, as well as being appropriate in terms of the increased man-power available[1]. Further, work of the in-depth phase of the Project raised some central educational issues which required consideration and these will be discussed later in this paper.

With regard to the work on Children's Classroom Experiences a methodology for the analysis of the experiences gained by children in the classroom setting was developed (Tasker, 1980). In addition, ways of portraying lessons which are useful both to the class teacher, and to others beyond the classroom, have been established (Tasker and Osborne, 1980). The task of extracting issues from the complex web of the many analysed lessons will be continued during 1981. One aspect of this work, the teaching of specific experimental skills, will form one aspect of the action-research phase of the project. However it is also expected that continued analysis of classroom lessons will provide valuable information to feed into the action-research evolving from the Working Papers 15-26 on aspects of children's science.

With regard to Children's Outlook on Science, the in-depth phase of the project will continue during most of 1981 as individual students are studied in considerable depth. It is also expected however that this work will contribute to some aspects of the action-research mentioned above by providing valuable information for instructional design.

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1 Mr Brendan Schollum, a chemistry teacher joined the Project in January 1981 for a year as a Visiting Teaching Fellow of the University of Waikato.

In Table II, the timetable for the Learning in Science Project with regard to the in-depth and action-research phases, and the interdependence of the various phases of our work, is outlined.

TOWARD ACTION RESEARCH

Our work in the in-depth phase of the project has demonstrated to us that children, even prior to entering intermediate school, often do have clear-cut views of the world and meanings for many words used in science lessons. Often these views and meanings are considerably different from the consensus view of scientists. Rather than being based on 400 years of intellectual endeavour, they are often pragmatic and self evident views based on, and largely compatible with, everday experience.

It is also clear to us from our studies that children's views of specific phenomena and meanings for particular words (see Working Papers No 15-26), as well as their tendency to view things in particular ways, e.g. egocentric and human-centred viewpoints, animistic viewpoint, reliance on the senses and so on, can be tenaciously held despite considerable exposure to science lessons.

In our view the nature, the prevalence and the resistance to change, of children's non-scientific views, are not fully appreciated either by teachers or by curriculum developers. We ourselves have been surprised, even intrigued, by the viewpoints children hold with respect to the words and views we have talked to them about. Moreover these children's views tend to be not just idiosyncratic, and where we are able to compare our findings with similar overseas studies we find New Zealand children are not alone in the views that they hold.

If teachers are unaware of the conceptions that pupils bring to their classes, and proceed to provide experiences based on an assumed background, it is perhaps not surprising that children's views frequently remain uninfluenced by classroom experiences, or that they are modified in unanticipated ways. Our work supports Ausubel's suggestion that instruction which ignores the conceptions which pupils bring with them

rather than taking them into account, is likely to make children's scientific misconceptions more elaborate and stable instead of extinguishing them (Ausubel et.al., 1978)[2].

If the above contentions are accepted then they raise some central questions, both in terms of strategies for teaching science and for the aims of science education itself. To explore these issues it is first necessary to consider aspects of both the content of science, and the processes of science, and their relationships to science teaching.

PROBLEMS RELATED TO THE CONTENT AND PROCESSES OF SCIENCE

Layton (1973) points out that science as an area of study has developed dramatically in a very short period particularly when compared with the total development of mankind: the major advances have taken place in the last 250 years compared with some 100,000 years. He suggests that

> "A necessary, although by no means sufficient, requirement for this remarkable surge of intellectual activity was the introduction into scientific thought of conceptions of which there were no directly observable instances ..... the ideas of linear inertial motion ..... the doctrine of atoms ..... By the use of theoretical entities, or constructs, which were not obviously derived from an everyday view of the world, but which were creative products of the scientific imagination, the explanatory and predictive powers of science were progressively increased..... The use of highly abstract concepts which are connected to experimental observations by complex logical relationships, in conjunction with the close liaison of experimental science and mathematics, has enabled science to achieve intellectual advances of unprecedented magnitude." (p168)

Layton goes on to suggest, however, that the very steps which have increased the power of science as a mode of intellectual enquiry has "generated formidable problems associated with its teaching". We have to deal with the abstract nature of the subject. Also the tendency of science to concentrate upon relatively simple phenomena and idealizations,

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2 Other possible interactions that may occur between children's conceptions and teaching are explored further in Freyberg and Osborne, 1980 and Gilbert, Osborne and Fensham, 1981.

e.g. frictionless trolleys and perfect reflectors of light,to the exclusion of much of the complexity and imperfection which characterize real life problems, leads to a detachment of the subject from everyday experiences. Hence although scientific knowledge may be useful to society through the development of applied science and applications, one might question if such knowledge is directly useful to the "man in the street".

In an attempt to encourage students to view things from a scientific perspective, there has been a tendency during the last two decades to bias the objectives of science teaching toward learning about the procedures of science and developing scientific knowledge using a discovery approach. Layton(1973) considers a basic flaw in this approach is the assumption it incorporates; that science is an activity that simply requires commonsense and that appropriate "skills" are the primary ingredients of doing productive work. There seems to be, he contends, no explicit recognition of the powerful role of the conceptual frames of reference within which scientists, and children, operate and to which they are firmly bound.[3] Also Layton considers that there are problems in expecting that a discovery approach ... where it is hoped pupils will get to think about scientific ideas in the systematic way that scientists do .... will enable the procedures of science to be learnt. First the adoption of a discovery approach in the teaching of science is not logically prerequisite to children obtaining an understanding of scientific procedures. Moreover on the basis of even the most superficial analysis of the nature of scientific activity, it seems clear that discovery methods will not necessarily enable children to think and work in ways characteristic of a successful practitioner of science.

With regard to this last point Layton suggests developments in science do not necessarily develop either from the induction of a theory[4] from experimental observations or simply by the refutation of a

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3 Layton's views here relate closely to comments about science and scientists made by Einstein, see Appendix. Einstein's views on scientists and science apply equally, we would suggest, to children and learning science.

4 Here the word theory is used in a narrow sense - an hypothesis, a tentative explanation, idea or model. It is not being used in the sense of an established scientific theory e.g. theory of evolution.

theory by an experiment - any theory, even at odds with certain experimental facts, is better than no theory. Rather developments often occur from a three cornered fight between two theories and an experiment. It follows from these ideas that if we seriously want children to gain anything other than the most naive and unsophisticated understanding of the procedures by which scientific knowledge grows and changes, then children should be placed in a position where they need to consider two alternative explanations, which they or others might have suggested, and the experimental evidence which determines their scientific fate. Alternatively they need their explanations confronted by experimental evidence which will lead them to develop alternative explanations. These must then be evaluated against their original explanation.

IMPLICATIONS FOR THE TEACHING OF SCIENCE

Let us now reconsider some of the ideas presented so far

(a) Children hold plenty of ideas and theories about how and why things behave as they do - ideas which can, within limitations, be logical and coherent. These ideas can be tenaciously held and may be modified in unexpected ways as the result of teaching.[5]

(b) Accepted scientific concepts are often rather abstract and do not follow readily from children's everyday experience nor do they always relate easily to that experience.

(c) Scientists, and children, are bound by their conceptual frames of reference and science frequently proceeds by the comparision of two explanations with an experimental result rather than the simple refuting of an explanation by an experimental result; inadequate explanations remain unless replaced by more adequate explanations.

How do these propositions impinge on how and what we teach? The first statement above, (a), suggests that learning must be considered more a process of modifying or changing existing ideas rather than just the

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5 This is likely to be particularly so if children views are not identified prior to instruction

filling of blank minds. The second (b) suggests that we have to accept that it may not be possible, or even desirable to attempt, to modify all children's ideas toward a scientific perspective. The third (c), suggests we might teach scientific ideas more effectively, and at the same time give children better appreciation of the nature of science, if we were to design learning experiences for children in such a way that children's predictions based on their ideas are compared, by them, with predictions based on the alternative ideas of others. Only <u>then</u> are experiments undertaken to test the opposing ideas (see for example Nussbaum and Novick, 1980).

Are these three suggestions mutually compatible with the situation in mixed ability classes? Let us explore further the idea that it may not be possible, or even desirable, to modify all children's ideas toward a scientific perspective. Van Aalst(1980) states

> "If we accept that common sense knowledge is pragmatic and self evident, we see how it contrasts with the system of science teaching whereby we try to stimulate pupils to set problems, to think about explanations and to create alternative explanations .... I think that for many pupils the gap between this type of school science teaching and common sense knowledge is too big. Adolescents seek social acceptance: there is an inceasing age clannishness. If an individual wishes to be accepted by his equals he must abide by their standards, or he will be an outsider. I think this puts serious limitations on school science teaching and especially on the development of scientific thinking. In an informal classroom environment common-sense thinking plays a role. A classroom environment that accepts common-sense ideas on the one hand and stimulates cognitive development in the direction given by scientific reasoning on the other constitutes one of the major challenges we face." (p413)

Some children undoubtedly have the capability, and are ready to understand and to appreciate abstract scientific ideas. They can compare and contrast their own ideas with a scientific view, they can accept that a particular scientific view is more powerful and satisfactory than their own view, and can accept the scientific view as their own. With such children lies the advancement of our scientific and technological culture. However we must accept that for some, even many children, it may

well be that in terms of their everyday lives there is little to be gained by their attempting to understand a scientific framework, e.g. Newtonion dynamics. If we can bring these pupils to an awareness that there is another framework which scientists find useful, but which they may not wish to accept as their own personal view, then we may have achieved as much as we would wish for these children. Finally for some children, all we might be able to expect in terms of this aspect of teaching science is that they acquire some new experiences about the ways in which things behave. Questions as to "how and why" may be neither of interest to them nor within their capabilities to grasp.

MODIFYING CHILDREN'S VIEWPOINTS

The ideas discussed in the preceding section lead to some very basic questions about what the aims of science teaching should be and how these aims might be most effectively achieved. Accepting for the present that we wish to encourage the development of a scientific perspective at least for some children - which particular children we may not be able to identify immediately - let us consider how this might be achieved.

Perhaps the most widely reported accounts of attempts to modify children's viewpoints has been those by Geory Delacote and others in France. Tiberghien (1980), for example, considers that we must accept that children have particular views; we must value these views and explore them; we must evoke from pupils, and, <u>if necessary</u>, offer,[6] alternative viewpoints; and we must encourage pupils to test opposing ideas experimentally.

Tiberghien (1980) spends a considerable proportion of her paper discussing a learning situation made available to a pupil, Marie-Noelle. While Marie-Noelle's experiences successfully changed her viewpoint toward a more scientific perspective, the same learning situation used with a second child was not successful. In discussing this work Tiberghien comes to the view that for successful teaching the child must be sufficiently motivated and have an adequate intellectual development to be able to ask <u>herself</u> questions and to restate questions asked in <u>her</u> terms. Then,

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6 Our emphasis and interpretation of Tiberghien.

"In order to answer these (her own) questions, the teaching sessions gave Marie-Noelle the opportunity to carry out the experiments, to discuss with other children and with the teacher and to consider relevant information given by the teacher. The experiments (she carried out) were the occasion of a confrontation between her opinion (invalidated by the experiment) and the opinion of the teacher or another child (conferred by the experiment). This stage seemed to us to be fundamental, the tension experienced by Marie-Noelle had allowed her to develop and reorganise her thoughts. This presupposes teaching conditions which supply the opportunity for this confrontation. This necessitates that through the teaching, the child recognises an alternative explanation to her own. The teaching must therefore clearly give the necessary information, by experiments, explanations by the teacher, by discussions, by reference books, etc. The personality of the teacher must allow him to accept the tension which is created, that is to say, allow the child to explain herself and to retain her point of view, without correcting her. The teacher must also be able to help the child to overcome these tensions.

It also assumes that the child must be capable of coping with the confrontation. This presupposes that she can make explicit her own interpretations (if they exist) and that she can retain them in order that they be confronted with others." (p 299)

Tiberghien concludes by suggesting two clearly necessary conditions for such learning:

(i) It is important that the child takes over the initiative to ask himself or herself questions about the interpretation of phenomena presented in lessons.

(ii) It is important that the child makes his or her personal interpretation and confronts that, along with alternatives proposed by others, with experimental findings.

What can be said in favour of the approach?

(a) It views teaching in terms of an operation which attempts to start with the child's view and to end with a modified child's view. The child's original ideas can be considered and valued. They can be

related to the views of peers and to the views that scientists held in the past[7] and hold now.

(b) The approach views the learning process in a similar way to Layton's view of scientific advancement; children, like scientists, will not change their view, or explanation simply by its being reputed with regard to one situation. They must first perceive a better view or explanation to replace the presently held view.

(c) The approach accepts the belief that sometimes children have to be offered an alternative viewpoint. Many scientific ideas are so contrary to intuition that children are almost certainly not going to think of them by themselves, e.g. the idea of atoms.

The approach outlined above is not new. However, it possibly gives a greater prominence to children's initial ideas than we have often given them in the past. It suggests, in our opinion, that it is necessary, prior to a teaching episode for teachers to have been made aware, through curriculum support material, of the types of views children hold, as well as of the scientific viewpoint expressed in children's language. This we believe will give the teacher confidence to cope with a situation in which a variety of viewpoints will undoubtedly be brought forward (if permitted) to be discussed and analysed. At present in our experience, many teachers restrict discussion and dogmatically state the scientific viewpoint often in sophisticated scientific language. These teachers are unsure where a free discussion will lead and feel unprepared to cope with the unanticipated ideas which children may bring forward. Curriculum materials must provide valid information about other teachers past experiences in adopting this approach. Here then is the need for action-research; to attempt trial lessons and to provide accounts of what occurs in such lessons. This might well include:

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7 Many children's views are similar to views held by scientists in the past. Aristotle had the views he did, not because he was a concrete thinker in Piagetian terms but simply because he did not have 400 years of scientific knowledge and understanding on which to build.

(i) Full details of the common responses made by children to particular teacher questions.

(ii) Information about how teachers handled particular questions from pupils.

(iii) Teacher and pupils comments on what they thought about the lesson.

If the aim of science teaching, for at least some children, is to encourage them to adopt a scientific perspective, is the above all that is necessary in the teaching of science? Undoubtedly it is not. Scientists have many conventions; they define concepts in ways useful to them but which conflict with commonsense experience and usage. These differences between defined scientific concepts and everyday concepts associated with the same label need to be made explicit using a wide variety of carefully chosen instances and non-instances in discussion. This may not involve experimental work at all[8]. Similarly other conventions, - for example, conventions scientists have adopted with regard to graphs and diagrammatic representations - must be gradually and carefully introduced. An excellent example of how this might be done with regard to electrical circuit symbolism is given by Durey (1980).

Also as Layton (1973) points out, one of the problems with children testing out ideas of their own, and of others, about how and why things behave as they do is that it "leads to an emphasis on viewing science as an inevitable progression to even greater degrees of abstraction and purity. It can lead to an emphasis on the stereotype of the pure scientist supremely oblivious to the applications and wider implications of his or her work. Science is studied as an end in itself". Many of the children who are capable of gaining a scientific perspective may not become scientists but they may move into applied fields. Their interest is in applications. Teachers, supported by curriculum materials, should show pupils how scientific ideas and models enable us to make sense of a

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8 It could involve discussion groups using the cards we have used in our interview work followed by class discussion which includes teacher explanation of why scientists have adopted the definition they have.

wide variety of everyday phenomena, and show pupils how specific scientific ideas have been applied in technology and industry. Later, at more advanced levels, we need to help pupils take a natural phenomenon or piece of technology and identify several features using their acquired scientific concepts (Fensham, 1980). If pupils can be placed in a position where they are able to recognise the efficacy of scientific ideas and where they can see the power of these ideas to make sense of the world then, we believe, the pupil's grizzle that "science is not relevant"[9] must surely fade.

SCIENCE FOR ALL

While the above ideas may be pertinent for those who are interested and capable of appreciating aspects of the scientist's view of the world, it seems reasonable as Van Aalst (1980) suggests that for some children this type of pure science is not for them. For example Tiberghien (1980), Drury (1980) and others in France place considerable emphasis on children verbalising their views and discussing them. Some children have few formulated ideas about how and why things behave as they do - what is, just is. To others, while they may have a view or a theory it is a rule for action and they are unable to verbalise it[10].

In almost all New Zealand situations at the Form 1-4 level we have to accept that we will have both able and less able children in the same class. How can we challenge and interest children of all abilities at the same time? Two possible solutions are proposed for discussion. Either we teach in the way outlined previously for capable students while at the same time ensuring that there are manageable and achieveable goals for the less able or we change the priorities of science teaching. We will discuss these two ideas in turn.

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9 When students say science is not relevant they can mean "not related to the way I think about how and why things behave as they do" or "not related to the natural or technological world" or both.

10 As anyone who has solved a manipulative puzzle knows, it is possible to be able to solve the puzzle before you can really explain how you do it.

(a) From science to technology

The methods of teaching outlined earlier with respect to the more able pupils may not be incompatible, in junior science teaching, with the teaching of those who are not ready to, do not wish to, or are unable to, modify their viewpoints. For some our goal may be simply to get them to appreciate that there are other views different from their own; that scientists are a group of people with a consensus view different from theirs but one that is found to be useful for some purposes. For others, the proposed method of teaching may simply provide opportunity for children to observe carefully and record data, to explore how things behave without being concerned at all with why they behave as they do. Whatever level of scientific thinking individual children are capable of we would wish to move at some stage, and sooner for the less able, from scientific ideas related to the topic to technological or applied science applications of the idea. It has become clear to us that we as teachers and curriculum developers must provide those essential links between scientific ideas and their application[11].

What does this mean in terms of how we might design a particular lesson? Let us consider this in the context of a classroom investigation where we wish to encourage children to develop ideas about water (vapour) in the air. As starting point we might ask children (age 11-13?) to watch a warm dinner plate covered in water slowly become dry.[12]

(a) We could ask pupils to predict what will happen and to formally record this. (individually 5 minutes)

(b) We would definitely want children to watch carefully and record in as much detail as possible what they saw happen.
(in pairs 10 minutes)

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11 For the less able the technological applications would not be supported by a full scientific understanding but it may be unrealistic to expect that they should.

12 One of the important aspects of this would be the need to introduce the topic in such a way that pupils see the situation as a worthwhile one to investigate. The problem the teacher has chosen for the pupils needs to become the pupil's problem.

(c) We would wish to encourage children to express their views about what they think has happened and why. We might need to guide them to ask "Where has the water gone to?" and to think about that question. (in groups of 4 or 5, 10 minutes)

(d) We would want pupils to discuss the variety of views put forward and, if it hasn't already been brought in, the teacher might introduce another view (the scientific perspective) but in a similar language to that of the children's views.

(class discussion, 10 minutes)

(e) Pupils might be encouraged to devise experiments to test out some of the different ideas proposed e.g. "the water has gone into the plate", "the water is in the air but in such small droplets that you can't see it", "the water has changed into air".

(some groups of able pupils, 1/2 a day!)

(f) Other pupils could be encouraged to investigate whether the plate dries faster if it is hot or cold, in the sun or the shade, or in a wind or no wind.

(g) Childrens' findings, whether of an abstract nature (from (e)) or of a more applied nature (from (f)), would then be related to as wide a variety of everyday examples and associated phenomena as possible.

It is suggested that the pupil records, in their books, might contain things like

(i) what we observed;

(ii) what we thought (possibly a variety of views);

(iii) what scientists now think about this.

and so on. For young children, and for less able older children, our teaching aim might be to achieve (a) and (b), and hence (i) only. For older, and more able, children we may be able to proceed to (c) and

(d)[13], and hence (ii), and even (iii). For others we might proceed to (f) directly, excluding (c) to (e). Where ever possible, and for a wide an ability range as possible, we should include aspects of (g).

The above approach is very much a science to technology approach. Lets now consider the alternative approach.

(b) From technology to science

Van Aalst (1980) suggests that it would be desirable to establish a hierarchy of goals in science education based on the prime importance of learning experiences relevant to real life situations. His suggestion, as a starting point for discussion, is that this hierarchy should be from practical technological skills to complex scientific thinking skills - the children's progression to these higher skills being dependent on interest and ability. We move from technology to science, rather than the previously suggested approach of moving from science to technology.

If we were to follow this approach what would our hierarchy of aims look like? Below we consider a tentative list, adapted from the initial ideas of Van Aalst, as a basis for discussion.

(a) Functional everyday skills

e.g. . the ability to read meters and repair electrical plugs
. the ability to observe carefully and measure accurately
. understand instructions for the use of technical apparatus and for carrying out manipulative tasks.

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13 This example is an interesting one in that the scientic view, that water is in the air but can't be seen rather than that it has changed into air, is unlikely to be thought of by students. However some students, even aged 10 or 11 are really intrigued by the phenomenon and want an explanation. It would seem not unreasonable to "sow the seed" of a scientific idea perhaps introducing it first as the idea of a child in another class or even as the idea of a group of men - not as an idea simply to be learnt.

(b) Functional recognition skills

e.g. . the ability to understand and interpret tabulated and graphical information
. the ability to wire a circuit given a circuit diagram
. understand newspaper tables and explanations of technical and natural phenomena

(c) Functional understanding skills

e.g. . the ability to suggest explanations for observed phenomena
. the ability to consider and evaluate opposing explanations
. understand, and appreciate, scientific explanations for familiar natural phenomena and everyday technological equipment.

(d) Functional productive skills

e.g. . the ability to apply scientific knowledge and scientific processes to solve a problem
. the ability to criticise an article or report on scientific grounds
. understand, and be able to generate understandings within, the knowledge structure of a particular discipline.

It would seem appropriate that the level (d) objectives would only apply to the senior secondary school and the university levels of education.

If we were to teach within the Van Aalst framework what does this suggested hierarchy imply in terms of designing a particular lesson? Let us return to the topic of water vapour in the air for 11-13 year old children. Perhaps this time we would start by pointing out the humidity readings in the daily newspaper. We might discuss the effects of this thing called humidity on humans and tell pupils that it is all to do with the amount of water in the air (in droplets so small we can't see them!). From this introduction we would get students to use some sort of

hygrometer (an instrument which measures the amount of water in the air.)[14]

* We would encourage students to cope with instructions for its use.
* We would encourage them to take readings and record their data.
* We would encourage them to extract the humidity reading from the local paper, and to tabulate or graph the information.
* We would encourage pupils to think about how this water gets into the air and what happens to it.
* Some pupils might investigate and explore their ideas by deliberately attempting to change the humidity in the room.
* We would want to consider the effects of water in the air, high humidity has a variety of effects on humans, things are difficult to dry, and so on.

(c) Which approach?

In the above discussion we considered two approaches to the teaching of technology and science. Which approach would be preferable in any particular situation undoubtedly depends on a multiplicity of factors e.g. the teacher, the pupils, the resources and the possible need for a variation in approach. Are there other possible approaches? Undoubtedly there are.[15] However it is hoped that the two approaches discussed previously will provide a sufficient basis for discussion.

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14 This particular topic may well be not a very suitable or practical one; certainly in terms of equipment which is familiar to children and currently available in schools. Nevertheless the teaching sequence is pursued so that it can be compared with, and contrasted against, the teaching sequence discussed earlier.

15 For example we have found that children's views are often similar to early ideas held by the Greeks or 14 Century Europeans. For certain topics an historical analysis of the various views held by thinkers and scientists and the reasons why they held those views may result in pupils modifying their own views in the light of their historical research. It would seem to us however that such an approach is only likely to interest the academically oriented pupils.

THE ACTION RESEARCH PHASE

It is with the wealth of data from the first two phases of the project, along with the issues that they raise and which we have touched on in this paper, that we move into the final action research phase of the Learning in Science Project. Rather than being in a position where we feel we have identified some basic problems for which we can provide simple and effective answers, we feel conscious that the issues we have discussed with teachers and pupils and raised ourselves, are not easily resolved and certainly not by us alone.

We see our task in the action-research phase as two fold.

(i) Our first task is to continue and extend our dialogue with teachers and curriculum developers about the problems that have been raised. Only by getting a wide acceptance of them as problems, and by arousing the enthusiasm of teachers and others for attempts to solve them, will our work have any long-lasting effect. Already a number of teachers throughout the country have been interested in our concerns and are trying innovative teaching approaches in an attempt to overcome specific issues raised by earlier working papers.

(ii) Our second task is to work with groups of teachers in the Waikato; to discuss with them which of the issues raised in particular areas they consider important and possibly solvable problems, to explore ways whereby these problems might be solved or at least alleviated in the classroom, to actually try out innovative procedures suggested by members of the group or others, and finally to report on this work in a way which will clearly indicate to others the potential and the problems of the particular innovations attempted.

At present we envisage four groups;

(a) a physics group, exploring issues raised in the working paper FORCE, FRICTION and GRAVITY

(b) a biology group, exploring issues raised in the working papers
LIVING, ANIMALS and PLANTS

(c) a chemistry group, exploring issues raised in the working papers
PHYSICAL CHANGE, CHEMICAL CHANGE and PARTICLES

(d) an experimental skills group, exploring issues raised in the working papers
FOCUS ON EXPERIMENTS and FOCUS ON PROCESS SKILLS

Depending on manpower and other factors a fifth group may be formed later in the year.

We hope that our particular choice of focus, influenced by the resources available to us and by our earlier work will not limit other teachers, or groups of teachers in other areas, choosing either the same or different topics to the ones we are working on.

Finally, let us set out some of our ideas as a set of rules which may be useful in planning instructional sequences.[16] At the least we believe they are worth serious consideration.

1. The instructional sequence should where possible initiate from the knowledge structure which is already possessed by the pupil, i.e. pupils views will need to be established as part of the approach or be predictable on the basis of earlier research.

2. The instruction should illustrate explicitly how new meanings which pupils are confronted with compare and contrast with other previous meanings (especially more restricted versus more general meanings) and provide the opportunity for pupils to test or compare alternative explanations through 'hands on experimentation'.

3. The instructional sequence should promote cross-referencing of learning content by relating a concept to other concepts and principles e.g. contrasting electric current with electrical energy and emphasizing that electric current is the same in all parts of the circuit. Also by exploring many instances and non-instances.

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16 Adapted from a list by Wiestra(1980)

4. The instruction should explicitly relate subject matter being discussed to daily life experiences and to industrial and technological applications.

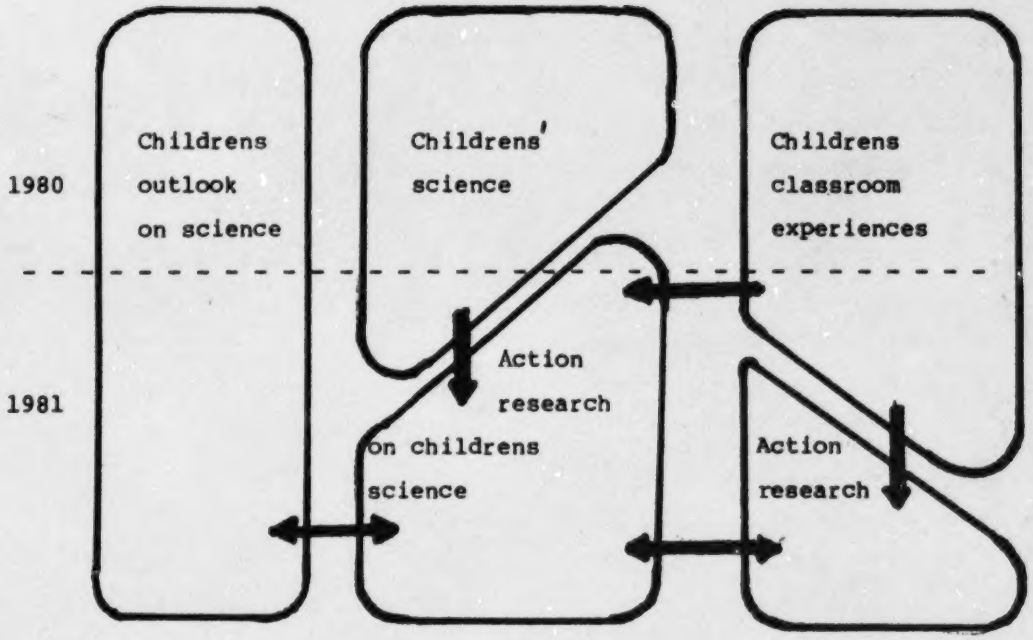
5. The instruction should be sufficiently adaptable so that those who cannot cope with abstract scientific ideas still find their experiences of science classrooms a challenging and worthwhile one.

Herein lies the challenge to us all.

Table I: The Topics of the In-depth Phase

		RESEARCHERS	ASSOCIATED PAPERS, ETC
			Freyberg & Osborne (1980)
CHILDRENS SCIENCE			Osborne (1980)
			Freyberg (1980)
16	FORCE	OSBORNE	Osborne & Gilbert (1980)
19	FRICTION	STEAD K/OSBORNE	Stead K. & Osborne (1981a)
20	GRAVITY	STEAD K/OSBORNE	Stead K. & Osborne (1981b)
17	ENERGY	STEAD B	Stead B. (1981)
26	PHYSICAL CHANGE	COSGROVE/OSBORNE	
27	CHEMICAL CHANGE	SCHOLLUM	
18	PARTICLES	HAPPS	
25	ELECTRIC CURRENT	OSBORNE/WILKINS	Osborne (1981)
22	ANIMALS	STEAD B.	Stead B. (1980a, 1980b)
24	PLANTS	STEAD B.	Stead B. (1980a)
15	LIVING	STEAD B.	Stead B. (2980a)
21	WEATHER	MOYLE	
23	LIGHT	STEAD B/OSBORNE	Stead B & Osborne (1980)
CHILDRENS' CLASSROOM EXPERIENCES			
28	A VISIT TO ANOTHER CLASSROOM	TASKER/OSBORNE	Tasker & Osborne (1980)
			Tasker (1980a)
			Tasker (1980b)
OVERVIEW PAPERS (about the Project in General)			
14	RECONSIDERING THE FRAMEWORK	OSBORNE et al.	Tasker et al. (1980)

Table II, The Learning in Science Project programme 1980/81



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Appendix Einstein on Scientists and Science

The following quote attributed to Einstein, (Lochhead and Clement, 1978) is about scientists and science. We would consider it equally true of children and learning science: We are all human. The emphasis is ours,

> The eyes of the scientist are directed upon thse phenomena which are accessible to observation... In an attempt to achieve a conceptual formulation of the confusingly immense body of observational data, the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk; and seldom if ever is he aware of the externally problematic character of his concepts. He uses this conceptual material, or speaking more exactly, these conceptual tools of thought, as something obvious, , ... given, something having an objective value of truth which is hardly ever, and in any case not seriously, to be doubted ... And yet in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not be unconsciously ruled by them."(p 34)

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